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Optimization of Turning Operation using Genetic Algorithm: Coding and Testing

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Abstract:*The industry today needs manufacturing operations of high production rate and economical machining to cope up with the changing trends and competition in the field. Optimization of turning operation is studied in this work and a Genetic Algorithm technique is developed and coded, so that further development can be done according to the area of implementation. The main aim of this work is the economical machining, ie., optimum tool life with maximum material removal rate, so the machining time can be reduced. For that, a high performance Genetic algorithm is aimed to develop to suit the various optimization problems in the Turning process and a comparative study will be done with Genetic algorithm toolbox in the Matlab software. The coded algorithm will be implemented in testing different experiments using different work material- tool combinations in future.*

I. INTRODUCTION

The industry today needs manufacturing operations of high production rate and economical machining to cope up with the changing trends and competition in the field. Even in the new era of Computer Numerical Control machines, the basic mechanical aspects of machining are determined by the humans itself and directed the machines to do the same. But currently, the field is transforming into an artificial intelligent level and so machines would be intelligent enough to identify the needs of the product to be manufactured. But that kind of technology is having high cost at the present stage and is practically unavailable at the time. So, developing advanced automation systems in the manufacturing field is a goal of the research now. The term Smart Manufacturing refers to the use of Information Technology at various application levels within the manufacturing systems in order to achieve optimized process, high efficiency and increased profit. As a step towards the above mentioned goal, optimization of machining process is studied in this work and a Genetic Algorithm technique is developed and coded, so that further development can be done according to the area of implementation. As a case study, a turning process in a CNC lathe is considered with given set of Work piece material and Tool material with some operational constraints. The main aim of this process is the economical machining, ie., optimum tool life with maximum material removal rate, so the machining time can be reduced. The Genetic Algorithm techniques is a heuristic optimization technique that mimics the evolution process in the nature, ie., survival of the fittest. The algorithm is highly flexible so that different kinds of it can be developed, changing is performance. The aim of this work is to develop a high performance Genetic algorithm to suit the various optimization problems in the Turning process and a comparative study will be done with Genetic algorithm toolbox in the Matlab software.

II. TURNING PROCESS

Turning is a metal cutting process used for the generation of cylindrical surfaces. Typically the work piece is rotated on a spindle and the tool is fed into it radially, axially or both ways simultaneously to give the required surface. The term turning, in the general sense, refers to the generation of any cylindrical surface with a single point tool. More specifically, it is often applied just to the generation of external cylindrical surfaces oriented primarily parallel to the work piece axis. The generation of surfaces oriented primarily perpendicular to the work piece axis are called facing. In turning, the direction of the feeding motion is predominantly axial with respect to the machine spindle. In facing a radial feed is dominant. Tapered and contoured surfaces require both modes of tool feed at the same time often referred to as profiling. Operating conditions control three important metal cutting variables: metal removal rate, tool life and surface finish. Correct operating conditions must be selected to balance these three variables and to achieve the minimum machining cost per piece, the maximum production rate and/or the best surface finish whichever is desirable for a particular operation.

III. GENETIC ALGORITHM

Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, andcrossover In a genetic algorithm, a population of candidate solutions (called individuals, creatures, or phenotypes) toan optimization problem is evolved toward better solutions. Each candidate solution has a set of properties (itschromosomes or genotype) which can be mutated and altered; traditionally, solutions are represented in binary asstrings of 0s and 1s, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals, and is an iterative process, with the population in each iteration called a generation. In each generation, the fitness of every individual in the population is evaluated; the fitness is usually the value of the objective function in the optimization problem being solved. The more fit individuals are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. A typical genetic algorithm requires:
1. A genetic representation of the solution domain.
2. A fitness function to evaluate the solution domain.

IV. OPTIMIZATION

Optimization or mathematical optimization is the selection of a best element from some set of available alternatives. An optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function.. More generally, optimization includes finding "best available" values of some objective function given a defined domain or a set of constraints, including a variety of different types of objective functions and different types of domains.

V. METHODOLOGY OF DEVELOPING GA

The work is aimed at developing a Genetic Algorithm(GA) which can be applied to optimize the turning process parameters to obtain maximum material removal rate. Even though it is initially developed for turning process parameter optimization, it can be easily applied to any optimization problems. This is applicable to a wide range of work material-tool combinations and so the effort made in developing the technique is worth it. The Genetic algorithm for optimizing the turning process is coded in Java considering the following factors.

Taylor's Tool Life Equation
$V T^n D^x Fy = C$
where V = Cutting Speed , T = Tool Life , D = Depth of Cut , F = Feed Rate

Material Removal Rate
MRR = V x F x D, where V = Cutting Speed = (Π d N) / 60 mm/s, F =Feed rate, D = Depth of Cut

The Machinery's handbook gives the optimum value of speed and feed combination for maximum tool life. As it is explained, the values are considered with maximum tool life, it may not be the optimum value for maximum material removal rate. So the purpose of thiswork is to search the possible values of feed, speed and depth of cut in accordance to the Machinery's handbook, which ensures the maximum tool life. So, in fact, it is a local search at some pre-determined range of values for the cutting parameters.

Problem Formulation
Maximum amount of material removed per tool
A = T x MRR *(need to Maximize A)*
where A = Amount of material removed , T = Tool Life,
MRR = Material Removal Rate

GA Development
The following criteria has been followed whiledeveloping the genetic algorithm. The coding has beendone in Java programming language.
Initial population size :8
Chromosome string size :8bit

Initial population generator : Pseudo RandomNumber Generator
Crossover type : Single Point crossover
Crossover point selection : Random
Termination criteria : After 2000 iterations

VI. RESULTS

After coding the algorithm, different simple test functions like polynomial equations has been solved using the program. The results of the test were impressive, most of the equations got converged at the desired solution. Yet, the algorithm needed to be improvised in order to get consistent solutions. As a concluding test, Rastrigin function is planned to be tested soon, which is a popular test function. After that, it will be implemented in testing different experiments using different work material- tool combinations.

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